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Direct and Indirect Relationships Between the Built Environment and Individual-Level Perceptions of Physical Activity: A Systematic Review.

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Running Head: Environment, Individual, and Physical Activity

Direct and Indirect Relationships between the Built Environment and Individual-Level

Perceptions of Physical Activity: A Systematic Review

## ABSTRACT

**Background:** Socioecological models highlight the potential direct and indirect effects of multiple levels of influence in explaining physical activity (PA). Social cognitive theories, however, position individual cognitions as the mediator of external factors such as the built environment when explaining PA. **Purpose:** To appraise the evidence for direct and indirect associations between the built environment and social cognition to predict PA. **Methods:** Literature searches were concluded in February 2019 using five common databases. Eligible studies were in the English language that included any direct and indirect tests of individual perceptions and the built environment with PA. **Results:** The initial search yielded 18,521 hits, which was reduced to 46 independent studies of primarily medium quality after screening for eligibility criteria. Findings were grouped by type of PA then grouped by the type of individual and built environment constructs within the model, and sub-divided by adult and youth samples. There was evidence that self-efficacy/perceived control accounted for the covariance between environmental accessibility/convenience and total PA, while habit accounted for the covariance in this relationship for transport PA, particularly in adult samples. There was no evidence that the built environment had a direct association with PA after controlling for individual-level factors. **Conclusions:** The results provide initial support for the mediation tenet in social cognition models for the relationship between individual, built environment, and PA. In practice, these findings highlight the need for coordinated interventions of individual and environmental change.

**Key Words:** social cognition, habit, self-efficacy, attitude, intention, accessibility, exercise, walking

## **BACKGROUND**

The benefits of regular physical activity (PA), defined as 150 min of activity per week at a moderate or vigorous intensity (1), has been established in the primary and secondary prevention of most major chronic diseases in adults such as heart disease, type 2 diabetes, several cancers and musculoskeletal disorders as well major psychological disorders such as anxiety and depression (2-4). Regular PA is also a critical health behavior among children and adolescents as it protects against high blood pressure, high blood cholesterol, metabolic syndrome, low bone density, depression, and obesity (5-7) and helps form the behavioral patterns that track into adulthood (8, 9). Unfortunately, few people in most developed nations engage in regular PA (10), with estimates as low as 20% meeting international PA guidelines (11, 12). Thus promotion of regular PA is a public health priority.

An understanding of the predictors and correlates of PA is considered essential to inform effective promotion efforts (13). Over the past 40 years, research applying theoretical frameworks to understanding PA has shown there are numerous correlates that span from biological and genetic factors to environment and policy aspects (13, 14). Given this breadth, the adoption of a socioecological approach to understanding PA has proven very helpful (15, 16). Socioecological models posit that behavior is influenced by multiple aspects ranging from higher-level policy to individual motivations (17, 18). The approach also acknowledges that PA can occur across many different contexts such as occupation/work, leisure, and transport and thus serve many different purposes (19).

Because the socioecological model is broad enough to accommodate all potential determinants of PA, it has also served great utility in bridging streams of PA research that had

focused almost entirely on individual-level social cognition, social factors, or on the built and natural environment (14). While this model therefore contains multiple potential levels to explore in terms of inter-relations with PA, the individual-level and the built environment-level have been a large focus of the research thus far (14). Social cognitive constructs such as self-efficacy, intention, and affective judgments have amassed considerable support as reliable correlates of PA (3, 13, 20-22). Similarly, sustained research on the built environment has shown that land-mix use, street or pedestrian network connectivity, safety, quality of PA infrastructure, and aesthetics are correlates of PA (23-27). The socioecological framework helps create a broad organizing structure for how these disparate factors may collectively affect PA (28).

One tenet of socioecological models, for example, is the potential for interactions across multiple levels of influence on behavior (28). A recent systematic review of the current evidence showed relatively few interactions between the built environment and social cognition when explaining PA (29). The authors found some evidence that intention may interact with the proximity that an individual resides around recreation facilities. Specifically, residing near recreation facilities augmented the relationship between intention and behavior so that individuals were more likely to follow-through with their intentions compared to individuals who reported living further away from recreation facilities. Still, the general conclusions from this recent review were that social cognition and the built environment rarely interact when explaining PA (29).

A more likely relationship between the built environment and PA with individual-level perceptions may be via direct and indirect means (30, 31). In terms of an indirect effect, the primary relationship of the environment upon PA may be mediated through individual-level cognitions. This proposed pathway is correspondent with the conceptualization of social

cognition models (32, 33), whereby perceptions of the built environment help form the basis of social cognitive factors, which in turn determine PA. For example, a built environment that has low accessibility to get from one point to another may produce beliefs that transport PA is difficult which contributes to both perceived behavioral control/self-efficacy appraisals and attitude/outcome expectations about the PA behavior. In this line of reasoning, the environment is a critical antecedent of social cognition and its effect on PA is through its effect on the social cognitive constructs. Mediation models (see Figure 1) suggest that this pathway is known as  $ab$ , where path  $a$  is the effect of the built environment on social cognition, path  $b$  is the effect of social cognition on PA, and  $ab$  is the mediated relationship between the built environment and PA via social cognition (34, 35).

Still, the influence of the built environment on PA may also be direct and independent of social cognitions (30). Indeed, Spence and Lee (31) consider this direct effect to be one of the essential properties of the socioecological model that distinguishes itself from social cognitive approaches. For example, it is possible that environmental accessibility affects PA independent of such rational and expectancy-based constructs such self-efficacy, social support, or attitudes. In these cases, the environment may be indicative of more automatic activations (36). In mediation models, this pathway is known as  $c'$  (34, 35) which is the path of the environment on PA independent of the relationship between individual perceptions and PA (see Figure 1).

Despite the burgeoning research using the socioecological model to understand PA, and several separate reviews on the built environment (e.g., 23, 25-27) and social cognitive (e.g., 3, 13, 20, 22) levels of the framework, we are not aware of any review of the evidence for direct and indirect (mediated) relationships between these levels. Therefore, the purpose of this review was to collect and appraise all studies, among all age groups and then subdivided by youth (<18

years of age) and adult (18+ years of age), where social cognition and the built environment has been investigated within a mediational frame of direct and indirect associations of PA behavior. The inclusion of both youth and adult samples in an amalgamated and sub-divided analysis supports the possibility for differentiated and collective findings among these populations. Specifically, from a theoretical perspective, age-related differences are not posited to affect mechanisms between the built environment, social cognitions or habit-based responses, and physical activity. Aspects of convenience/accessibility would be expected to inform self-efficacy/perceived control expectations as a general mechanism independent of age (37). Similarly, effects of the environment through more automatic activation, such as habit formation, are not viewed as age-specific mechanisms, but instead a function of repeated behavior in the same environmental context (38, 39). By contrast, there may be findings unique to youth and adults because built environment antecedents can vary (40, 41), thus altering the potential constructs included in the models of direct and indirect effects on PA.

## **METHOD**

This systematic review was conducted and reported in accordance with the Preferred Reporting Items for Systematic reviews and Meta-Analysis (PRISMA) guidelines (42).

### **Eligibility criteria**

Eligible studies met the following inclusion criteria: a) a measure of PA (self-report or objective) as the dependent variable; b) a measure of physical environment (perceived or objective); c) a social cognition or perceived individual-level factor of PA; d) a formal mediation analysis of the built environment positioned as an antecedent of the individual-level factor (e.g., indirect effect analysis, path analysis); e) not representing repeated results using the same datasets; and f) quantitative results. Reports had to be published in English language peer review

journals or theses to be eligible. No specific restrictions on population, types of environments, or duration of study were imposed.

### **Information sources, search strategy and study selection**

Literature searches were conducted in the following five databases including MEDLINE, Embase, PsycINFO, SPORTDiscus, and Web of Science, using keywords and phrases associated with social cognitive and environmental constructs in PA (Supplementary Table 1). The search strategy was developed by all authors. Publication date of the review was restricted to November 13, 2018. The searches were restricted by English language and human participants, but did not limit publication date or study design. In addition, a manual cross-referencing of bibliographies was also completed.

We managed study selection using Clarivate Analytics EndNote X7.7. After identifying and removing duplicate records by using EndNote and by hand (from 15 Nov to 15 Dec, 2018), one reviewer (RZ) screened the title and abstract of each study. The remaining studies that were obtained in full text was then screened for eligibility by two reviewers (RZ and CQZ). The reference lists of selected articles were then checked by the same two reviewers to search potential articles. Based on Orwin's (43) benchmarks (fair agreement, Kappa = 0.40-0.59; good agreement, Kappa = 0.60-0.74; excellent agreement, Kappa = 0.75 or more), there was a good agreement between the two reviewers making inclusion/exclusion decisions (Kappa = 0.728; see Supplementary Table 2). Discrepancies were discussed by all authors to reach consensus. Study selection was completed at the end of February 2019.

### **Data collection process and data items**

One reviewer (RR) conducted the initial data extraction using a 13-item data extraction form (see Supplementary Table 3), which was independently fact-checked by the other two

authors. The extracted data included authors, sample size and population, study design and setting, theory, measurement tools, and outcomes. As well, data items specifically sought were 1) built environmental attributes, 2) social cognitive or related individual-level constructs, and 3) type of PA behaviour assessed (simplified to total PA, MVPA, leisure-time PA, transport PA), and 4) mediation findings.

### **Risk of bias assessment**

An assessment of variability in study reports was conducted to gauge risk of bias and complete reporting in the included studies (Supplementary Table 4). A six-criterion methodological quality assessment (44), based originally on the STROBE statement (45) was conducted for each study independently by CQZ and RZ. The instrument included core content coverage (46) of appropriate selection of participants (participant eligibility criteria, participant selection criteria), appropriate measurement of variables (acceptable reported measurement details of physical activity and the proposed correlates), and appropriate analysis considerations (adequate power to detect the hypothesized relationships, acceptable attrition). The six criterion were answered with a yes (1) or no (0) format. High quality (low risk of bias) was considered with a score of five or six, moderate quality was considered with scores of three or four, and low quality (high risk of bias) was considered with scores of zero to two. Any differences in scores were reconciled among the authors.

### **Analysis**

Following initial read-throughs of the studies, themes for the types of direct and mediated effects were developed. Themes were created where at least two studies had investigated a similar pathway (i.e., path A, B, AB, and C'). Findings were then grouped by type of PA outcomes which included activities performed for leisure, activities performed for transport, total

PA, and total moderate-vigorous PA (19). This categorization approach has been performed in prior reviews with the built environment (25, 47). Among individual-level constructs, themes were developed using the basic categorizations by Fishbein et al. (48). This included perceived benefits/attitude, enjoyment/affective judgments, perceived barriers, subjective norm, social support, self-efficacy/perceived control, intention, and the nonconscious construct of self-reported habit. Finally, categorization of the built environment constructs followed the taxonomy proposed by Alfonso (49), which included accessibility/convenience (land-mix use, connectivity, walkability, etc.), safety (crime, traffic), comfort/quality (infrastructure quality), and aesthetics/pleasurability (neighborhood greenery, interesting views, etc.). For most of the studies reviewed, environment was operationalized, either through objective measures or perceptions, as the neighborhood or area around respondents' residence.

Given that many studies use multiple indicators of a particular environmental category (e.g., objective and self-reported measures of accessibility/convenience), we compiled all tests within each study and used the reliability of these tests to determine whether the study should be flagged as a significant pathway in the comparisons across studies (see Supplementary Table 3). Keeping with the exploratory nature of this review, we made the decision that if 50% or more of the tests in a given category (e.g., several tests of safety) within a study were significant, the paper was flagged as significant for comparisons across other studies similar to the approach in Rhodes et al. (29). The rule was deemed necessary in three of the accessibility/convenience measure studies (50-52), one study with multiple measures of social support (53), and three studies with multiple measures of safety (50, 51, 54).

Our analysis across studies collated the results of each pathway (A, B, AB, C') by type of PA. Based on Sallis et al.'s (55) rubric for determining valence and consistency of findings, a

theme was considered to: 1) have a positive pathway if there was a positive association if greater than 59% of studies reported this effect; 2) a negative effect if greater than 59% of studies reported this relationship; 3) inconclusive if 34-59% of studies found an association in a given pathway; and 4) no association if less than 34% of studies showed an association. Statistical significance ( $p < .05$ ) needed to be present to conclude an effect. Analyses were presented collectively and subdivided by youth (<18 years of age) and adult (18+ years of age) samples. A further sub-analyses of these results was also conducted by objective/self-reported measurement of the built environment, and objective/self-reported PA using the same approach where possible.

Meta-analysis was precluded because there was extensive heterogeneity in the measures, statistical tests employed, number and type of predictors in each equation, definitions of predictors, and study designs, all of which impact the ability to accurately pool the studies for quantitative synthesis (56).

## RESULTS

### Study Selection

As shown in Figure 2, the electronic database search yielded 18,521 potentially relevant records. Of those, 6319 duplicate records were moved and the remaining 12,202 records were screened by titles and abstracts. In the remaining 244 records, 201 studies were excluded because they did not a) conduct a formal mediation analysis ( $n = 137$ ), b) measure any physical built environment factor ( $n = 21$ ), c) measure any psychosocial factor ( $n = 28$ ), d) examine PA as a dependent factor ( $n = 8$ ), e) write in English ( $n = 1$ ), f) represent quantitative results ( $n = 4$ ), and g) include the b path ( $n = 1$ ). In addition, we excluded one article in which repeated results were represented using the same datasets with one of the eligible articles. A total of 46 studies passed the inclusion criteria and were included for analysis (Supplementary Table 3).

## Study Characteristics and Measures

Table 1 describes the characteristics of the 46 studies included. These eligible studies represented a total of 35,076 unique participants, with the sample sizes ranging from 200 to 2,650. The mean study sample size was 762.59 ( $SD = 628.214$ ). The majority of studies comprised of adult populations ( $n = 27$ , age range = 18-59), yet six studies included older adults (age range = 60+) and 12 studies included children ( $n = 4$ , age range = 0-12) and adolescents ( $n = 9$ , age range = 13-17). The majority included both males and females ( $n = 36$ ), with 10 specifically addressing women. Geographical representation was broad including Australia ( $n = 4$ ), Brazil ( $n = 2$ ), Canada ( $n = 8$ ), China ( $n = 2$ ), Europe ( $n = 5$ ), Korea ( $n = 3$ ), United Kingdom ( $n = 4$ ), United States ( $n = 16$ ), Iran ( $n = 1$ ), Japan ( $n = 1$ ) and New Zealand ( $n = 1$ ). Risk of bias analyses showed that one study was high quality, 31 studies could be considered medium quality, and 14 studies were rated as low quality (see Supplementary Table 4).

Assessments of PA included validated self-reported measures ( $n = 21$ ), accelerometer data ( $n = 9$ ) and study-created questionnaires ( $n = 17$ ). Environmental data were measured through tools such as spatial measures derived from Geographic Information Systems databases ( $n = 9$ ), the Neighborhood Environmental Walkability Survey ( $n = 14$ ), and other questionnaires ( $n = 30$ ). Similarly, a large number of social cognitive theories, especially Social Cognitive Theory ( $n = 24$ ), and Theory of Planned Behaviour/Theory of Reasoned Action ( $n = 15$ ) were used.

## Total Physical Activity

Sixteen studies examined the relationships between social cognitive constructs and built environment variables to predict total PA. Path A analyses (Supplementary Table 5) showed that accessibility/convenience predicted self-efficacy/perceived behavioral control in five (50, 57-60)

of seven studies, but was not linked to subjective norm (57, 61) or perceived benefits/attitude (59-61). This link between accessibility/convenience and self-efficacy/perceived behavioral control was found for both adults in three (50, 59, 60) of four studies and youth in two (57, 58) of three studies. The effect of neighborhood safety had mixed findings on self-efficacy/perceived behavioral control and social support. Specifically, two (50, 62) of five studies showed a significant relationship between safety and self-efficacy/perceived behavioral control and one (54) of two studies showed a similar effect for safety on social support. Self-efficacy/perceived behavioral control had no relationship with infrastructure quality (58, 60, 63) and aesthetics (57, 63). All other potential relationships between the built environment and social cognition had too few results to yield findings.

Path B analyses predicting total PA (See Table 2; Supplementary Table 6) found significant effects for attitude/perceived benefits (60, 64), however this path has only been explored in adult samples. By contrast, social support (58, 60, 65-67), and self-efficacy/perceived behavioral control (50, 57-66, 68, 69) had consistent effects on total PA in both youth and adult samples. Intention (50, 61, 70) had an effect on total PA overall, but this was largely from the consistency in youth samples (61, 70). Path C', however, showed no significant effects for any environmental variable on total PA regardless of the population sampled.

Path AB analyses showed a significant covariance accounted for accessibility/convenience and total physical activity via social cognition in the majority of studies that formally tested for this effect (50, 59, 60), yet this result was exclusively for adult samples. The covariance was accounted for via self-efficacy/perceived behavioral control (50, 59), intention (50), and perceived barriers (60) in these studies. There was mixed evidence on

whether quality of infrastructure had a significant AB association with social cognition when predicting total PA, with Sniehotta et al. (50) showing that quality was mediated via self-efficacy/perceived behavioral control and intention, yet Hwang and Kim (60) did not yield a similar result. Both samples were adults; no studies have explored this effect among youth. An effect of safety on total PA was not accounted for by social cognition in the majority of studies (54, 61, 66, 67) and there were insufficient studies at present to appraise whether social cognition has any AB path with environmental aesthetics.

Our sub-analyses of these results by objective/self-reported measurement of the built environment and PA generally showed limited differences among the findings. Intention had a consistently significant Path B on total PA when measured with accelerometry (50, 61, 70) but not when measured with self-report (57, 64).

### **Moderate and Vigorous Intensity Physical Activity**

Fourteen studies examined the relationships between social cognitive constructs and built environment variables to predict MVPA. Path A analyses (Supplementary Table 7) showed that an aggregate built environment index predicted social support (71-73) but not self-efficacy/perceived behavioral control (72, 73) among adult samples (there was insufficient evidence to appraise the effect on youth). Accessibility/convenience had an effect on self-efficacy/perceived behavioral control in three (52, 74, 75) of four adult samples, yet no relationship in youth samples (76-78). Safety, however, was not associated with self-efficacy/perceived behavioral control (52, 75) among adult samples, and there was insufficient evidence to appraise the relationship among youth. Similarly, infrastructure quality showed no relationship with self-efficacy among adults (52, 73, 74), and had insufficient evidence to appraise its relationship with youth. Other social cognitive factors had too few tests among the

samples to appraise a relationship. Environmental aesthetics also had extremely limited tests of associations with social cognitive variables, but there was no evidence for its relationship with self-efficacy/perceived behavioral control (52, 75) in adult samples.

Self-efficacy/perceived behavioral control (52, 71, 72, 75-77, 79, 80), and intention (61, 78) predicted MVPA in the Path B analyses (see Table 3; Supplementary Table 8), but self-efficacy results were comprised primarily of adult samples and intention results were comprised of youth samples. By contrast, perceived benefits/attitude (71, 72, 74), affective judgments (79-81), and social support (71-73, 80, 82) had no direct path B association on MVPA, while subjective norm, perceived barriers, self-regulation behaviors and habit had mixed or insufficient evidence at present. No built environment characteristic predicted MVPA in path C' after controlling for social cognitive variables in path B, although most of the tests at present have been with adult samples. However, four (74-76, 78) of 10 studies identified an indirect effect of accessibility/convenience on MVPA through social cognitive variables and habit, suggestive of mixed evidence for this AB association at present. Sub-analyses by age group showed that the positive relationship was driven by youth samples more than adults, because adults showed a non-significant AB path in four (52, 73, 79, 82) of six tests. The factors that accounted for significant covariance were self-efficacy (74-76), self-regulation behaviors (74), perceived benefits (74), and habit (78). No other environmental variable showed evidence of an AB pathway, yet most of the present research has been conducted with adult samples.

Finally, sub-analyses showed no evidence that the measurement of the built environment (self-reported, objective), or the measurement of MVPA (self-reported, accelerometry) was related to variability in significant findings of the B, C' or AB pathways.

### **Leisure-Time Physical Activity**

Fourteen studies examined the relationships between built environment variables, social cognitive constructs and leisure-time PA. The studies were comprised of adult samples with the exception of one study (83). In path A analyses, an aggregate index of the built environment predicted social support in three (65, 71, 72) of four studies but had no association with self-efficacy/perceived behavioral control in two (72, 84) of three studies (Supplementary Table 9). Convenience/accessibility predicted self-efficacy/perceived behavioral control in the majority of studies (85-88), but was either unrelated to (i.e., attitudes/perceived benefits, subjective norm) or had mixed evidence with (i.e., perceived barriers, affective judgments) most other social cognitive constructs. Environmental safety predicted both perceived benefits (83, 85) and self-efficacy/perceived behavioral control (85, 86) but was not related to subjective norm (85, 86). On the other hand, infrastructure quality was unrelated to attitudes/perceived benefits (85-87, 89, 90), perceived barriers (87, 90), subjective norm (80, 85, 86, 89), and self-efficacy/perceived behavioral control (86, 87, 89, 91). Infrastructure quality was only a reliable predictor of affective judgments (80, 86, 91) of leisure-time PA. Finally, environmental aesthetics was a predictor of attitude/perceived benefits (83, 85, 88, 89), affective judgments (86, 88, 89, 91), and subjective norm (83, 86, 89, 91), but had mixed findings for its effect on self-efficacy/perceived behavioral control with three (83, 85, 89) of six studies showing positive associations.

Path B, C', and AB analyses can be found in Table 4 (also see supplementary Table 10). Perceived benefits/attitude (71, 83, 86, 87) and intention (83, 85, 88, 89, 91, 92) were reliable predictors of leisure-time PA in path B. All other social cognitive constructs had mixed findings (i.e., affective judgments, social support, self-efficacy), no relationship (perceived barriers, subjective norm), or insufficient evidence to appraise (self-regulation behaviors). An aggregate environmental index predicted leisure-time PA in two (71, 84) of three studies, but no specific

environmental factor was a direct predictor of behavior in path C' analyses. Similarly, no environmental factor had its variance accounted for via social cognitive constructs in path AB analyses to predict leisure-time PA. Objective vs. self-reported measurement of the environment and physical activity did not appear to moderate the findings.

### **Physical Activity for Transportation**

Nine studies examined the relationships between built environment variables, social cognitive constructs and PA for transport. In path A analyses, all of these studies featured adult samples. An aggregate index of the built environment predicted attitude/perceived benefits and self-efficacy/perceived behavioral control (93, 94), but all other analyses had insufficient studies to evaluate the patterns (see Supplementary Table 11). With the exception of one study (51), all studies available for path B, C' and AB analyses were with adult samples (see Table 5; supplementary Table 12). Only habit predicted PA for transport in path B analyses (95, 96). By contrast, affective judgments (86, 92, 96), subjective norm (86, 93, 96), and social support (82, 92, 96) showed no relationship with PA for transport, while attitude/perceived benefit, self-efficacy/perceived behavioral control, and intention had mixed findings. The built environment showed no significant effects in path C' analyses on PA for transport, yet three of five studies found a significant AB path of convenience/accessibility on PA. This effect was mediated via habit in two studies (95, 96) and self-efficacy/perceived behavioral control in the other study (86). The AB path for environmental safety had mixed findings and there was insufficient research at present to examine any other AB effects.

In sub-analyses, we found that path B analyses featuring intention were less likely to be significant when objective measures of the built environment were included in the equations (92, 96) compared to when these assessments were self-reported (94, 95). We found no other patterns

between self-reported and objective assessments of the built environment that explained variations in the findings.

## DISCUSSION

The purpose of this review was to collect and appraise all studies, among all age groups and subdivided by youth (<18 years) and adults (18+ years), where social cognition and the built environment has been investigated within a mediational frame (of direct and indirect associations) to predict PA behavior. To this end, 46 studies (34 focused on adults; 12 focused on youth) were reviewed that met inclusion criteria. Our analyses allowed for an exploration of these effects across four classifications of PA (total PA, MVPA, leisure-time PA, and PA for transport) and a broad assortment of social cognitive constructs (perceived benefits/attitudes, perceived barriers, affective judgments, subjective norm, social support, self-efficacy/perceived behavioral control, and intention) as well as the nonconscious construct of habit. Furthermore, we implemented a sensible taxonomy of built environment characteristics (accessibility/convenience, safety, comfort/quality aesthetics/pleasurability) in which to understand our findings. The reports collectively represented over 35,000 participants from 11 countries in mostly cross-sectional designs, of medium quality. The studies were extremely heterogeneous in their assessments of PA ranging from active transportation to leisure time PA, as well as in their appraisals of built environment constructs and putative mediators. For example, sources of environmental measures ranged from the use of Geographic Information Systems, surveys, to open source tools to evaluate various aspects of the environment and 38 studies contained study-specific (idiographic) sets of social cognitive mediators. Thus, the available sample of studies represents a rich data-set to appraise the state of current evidence in a first attempt to organize findings and propose areas for future research.

We analyzed the overall relationships between the built environment and social cognitive constructs among the reviewed articles (i.e., Path A). Overall, this was the pathway that has been investigated the least in socioecological models of PA, with nearly  $\frac{1}{4}$  of studies ( $n = 10$ ) failing to report on these relationships. As a result, many of the pathways between the built environment and social cognition have insufficient data at present to appraise an association and this requires more concentrated future research. The most reliable association, however, appears to be a positive association between environmental accessibility/convenience and self-efficacy/perceived control, particularly among adults. The finding makes intuitive and theoretical sense because improvements in accessibility/convenience is meant to directly increase the efficiency of PA from one destination to another. Lack of access to PA is a frequently reported barrier of self-efficacy/perceived behavioral control (97, 98) so it stands to reason that improvements in accessibility/convenience would improve self-efficacy/perceived behavioral control. Further, accessibility/convenience was not linked to attitudes (or perceived benefits) and subjective norm in the majority of studies, supporting the utilitarian effect of this characteristic of the built environment via self-efficacy/perceived behavioral control and not its potential impact on the appraisal of PA motives or perceived outcomes.

Path B analyses overview the connections of the individual-level constructs to PA (34, 35). We found reliable evidence for the role of intention (mainly among youth), followed by self-efficacy/perceived behavioral control (mainly among adults) and attitudes/perceived benefits as predictors of PA. These findings are congruent with social cognitive theories applied to PA where intention and self-efficacy in particular are considered the proximal antecedents of behavior (14). The findings also mimic prior meta-analyses and reviews showing that intention and self-efficacy/perceived behavioral control are the most reliable predictors of PA among

social cognitive constructs (3, 13, 20, 99). An interesting caveat, however, was in the domain of transport PA. Transport PA showed mixed evidence for social cognitive predictors and instead had evidence that habit was the primary predictor of PA. The findings thus far relate mainly to adults because of so few studies have been conducted with youth. While the finding needs further replication, it makes sense from a theoretical standpoint. Habits are cued-behavior responses that require lowered conscious deliberation to enact (100, 101). They are formed via behavioral repetition under the same circumstances (i.e., the same initiating cues) (102, 103). PA for transportation in the studies reviewed was typically measured in the context of transportation to school or work, which are likely structured around similar daily routines compared to leisure-time PA or total PA, and thus align with the premise of habit formation. The results underscore the importance of studying different types of PA, as they could yield different antecedents and thus need targeted intervention approaches (19).

The analysis of the indirect and direct relationship between the built environment and PA proved particularly interesting. First, we found no convincing evidence that the built environment has a direct relationship with PA after controlling for key social cognitive variables or habit in adult or youth samples. Thus, the tenet of socioecological models that the built environment can have a direct effect on behavior after controlling for individual factors was not supported (31). Instead, we found some support for the indirect association of accessibility/convenience and PA that could be accounted through covariance with social cognition and habit among adults. Findings are too preliminary at present to discern whether this finding extends to youth. Still, the most common factor associated with this covariance in the adult studies was self-efficacy/perceived behavioral control in total PA, and habit in PA for transport. These results mimic the findings of our path A and B analyses as well as bivariate

associations between the built environment and PA where accessibility/convenience has the most reliable link with PA compared to other environment factors (104, 105). Thus, our review amalgamates the research on built environment and individual factors to show that the most likely mechanism these factors link to PA is via accessibility/convenience affecting self-efficacy/perceived behavioral control appraisals or the formation of habits, which in turn predict the likelihood of PA. Interestingly, this finding supports the theoretical tenets of dual process theories (106) and suggests that the environment may affect both conscious deliberative cognitions such as self-efficacy but also the effectiveness of executing habits (30).

From an applied perspective, the results highlight that a connected and accessible environment for PA may be important to enable subsequent volitional and automatic antecedents of behavior. The results underscore the public policy and health promotion implications of this review. Namely, that individual cognitions and habits connect with the built environment to explain PA. Thus, investments in upstream infrastructure, particularly those that improve connectivity/accessibility, may be critical to successful promotion efforts at the individual-level (15, 107). Our review has also focused only on the built environment and individual levels of the socioecological model. Future reviews focused on factors such as the natural environment and the social environment may complement the information in this review when combined with either built-environmental or individual factors.

Despite notable findings in this review, there are limitations to our evidence at present. First, the available analysis clearly contained more adult studies compared to adolescents and children, and thus most of the findings as they relate to youth should be considered preliminary. Ultimately, we had too few studies among samples to differentiate whether there are mechanistic differences between the built-environment, individual factors, and physical activity, among

adults and youth. These findings warrant re-examination when more research is available to provide evidence that is more conclusive. Second, we also amalgamated objective/self-reported measures of PA and the built environment in our findings. Like our analyses by age of the sample, we saw few differences among these different measurement approaches, but it would be useful to revisit these findings as more research becomes available.

There were also some limitations of the review methods. This literature review is limited by the search terms and search engines employed as well as studies in English. Our review was delimited to studies that had applied a frame that allowed for both indirect and direct associations between the environment and individual factors. Thus, our results likely do not represent all studies that have included B and C' associations in the absence of A and AB associations. Our analysis methods were also biased toward flagging any effect within a category of the built environment or social cognition at 50%+ evidence of the findings. We believe this is an appropriate first assessment of the direct and indirect effects within the socioecological model but a more refined analysis in the future that focuses on effect size may yield different findings. Furthermore, using a single author to screen the titles and abstracts of articles may increase the possibility that relevant articles would be discarded. Finally, our analyses method across studies was able to show general signal detection patterns of indirect and direct paths between environmental and individual predictors upon behavior, but estimations of the magnitude of these effects requires future meta-analytic analyses. We recommend that future research employ complete model tests of a given theory (e.g., SCT, TPB) to reduce the heterogeneity of the purported mediating variables in these equations and thus better enable a coherent meta-analysis.

## **CONCLUSIONS**

In summary, to our knowledge, this is the first review examining evidence for the direct and indirect effects of PA prediction models that include the built environment and individual perceptions of PA. Our results of 46 studies showed there was evidence that self-efficacy/perceived control accounted for the covariance between environmental accessibility/convenience and total PA, while habit accounted for this relationship for transport PA, particularly among adult samples. Further, intention, self-efficacy/perceived behavioral control, and perceived benefits had direct relationships with total PA, MVPA, and leisure-time PA, while habit had a direct relationship with transport PA. There was no evidence that the built environment had a direct relationship with PA when controlling for individual-level factors. Of note, there were fewer findings among youth samples compared to adults, so this remains a key future direction and the findings may change as this area of research matures. The results provide initial support the interrelations between individual cognitions, the built environment, and PA and highlights how promotion of environmental change may integrate with individual-level PA change.

## DECLARATIONS

Consent for Publication. All authors consent to have their names on this manuscript and take responsibility for the work in its entirety.

Conflicts of Interest The authors report no conflicts of interest.

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Figure Caption:

Figure 1: Path Model of the direct and indirect relationships between the built environment and individual factors on physical activity

Figure 2: PRISMA Flow Diagram. Caption: Source inclusion process. Adapted from PRISMA Statement, Moher et al., 2009

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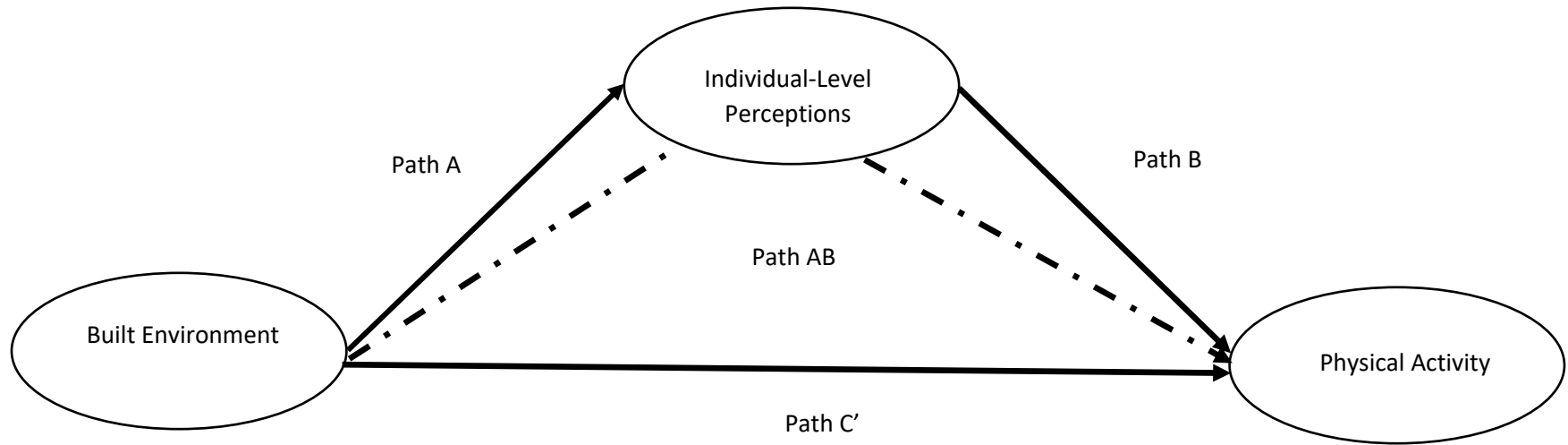
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Figure 1



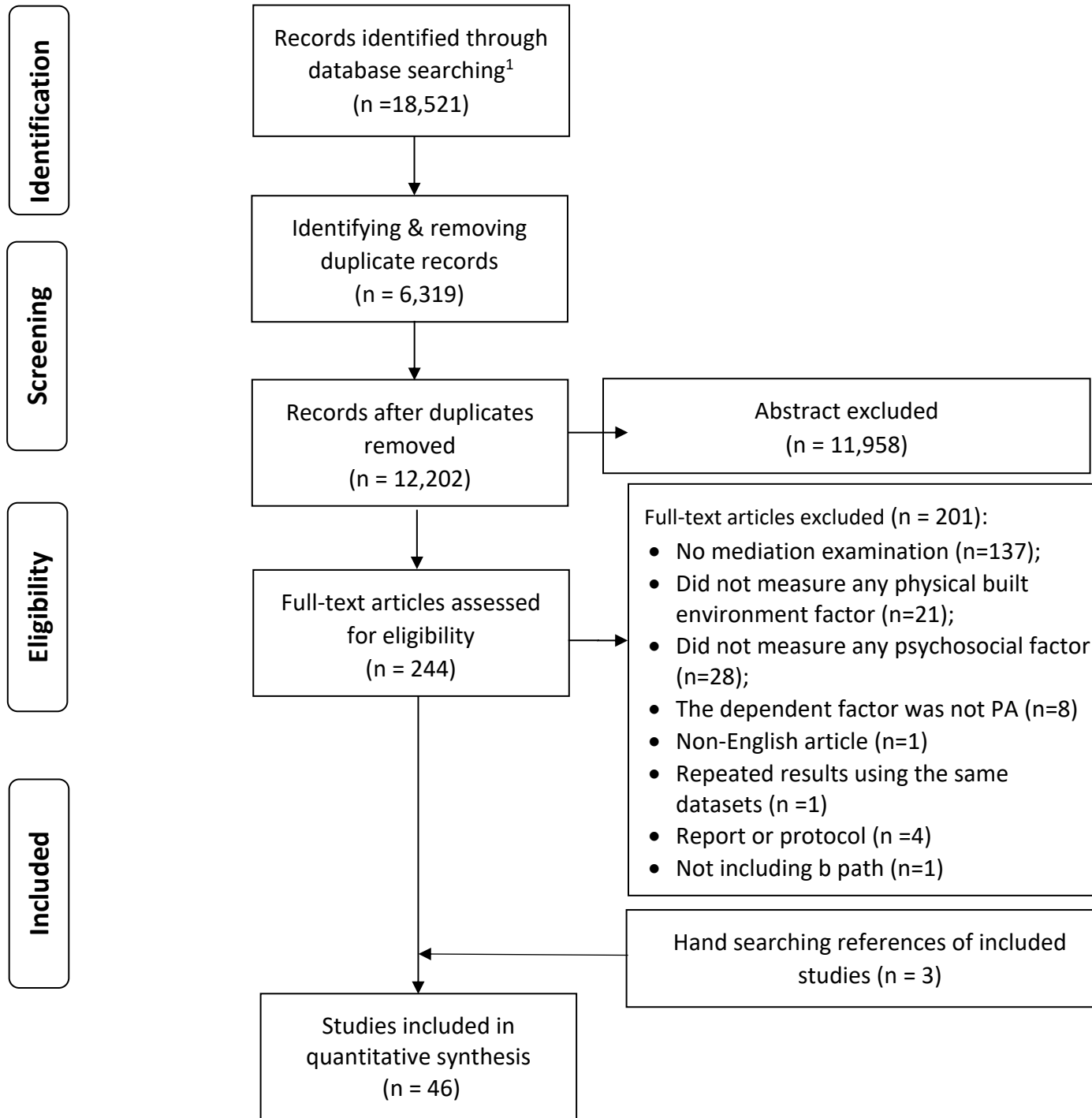


Figure 2. Flow chart of the systematic literature search<sup>1</sup>  
Table 1

<sup>1</sup> In the 18521 publications, 2167 of them were identified from Ovid MEDLINE, 3252 were from Ovid Embase, 2403 were from PsycINFO, 1642 were from SPORTDiscus, and 9057 were from Web of Science. Species: human; Search fields: title and abstract.

*Overall study characteristics*

Characteristic	Number of studies	Percentages
Total samples (N = 46)		
Location		
Australia	4	8.7
Brazil	2	4.3
Canada	8	17.4
China	2	4.3
Europe	5	10.9
Korea	2	4.3
United Kingdom	4	8.7
United States	16	34.8
Other (Japan, Iran, and New Zealand)	3	6.5
Study design		
Cross-sectional	37	80.4
Longitudinal	9	19.6
Age		
Children (0-12 yrs.)	4	8.7
Adolescents (13-17 yrs.)	9	19.6
Adults (18-59 yrs.)	27	58.7
Older adults (60+ yrs)	6	13.0
Gender		
All female trial	10	21.7
All male trail	0	0.0
Both gender trail	36	78.3
Types of physical activity		
Total PA	16	34.8
MVPA	14	30.4
LTPA	14	30.4
PA for transportation	9	19.6
Theoretical framework		
SCT	24	52.2
TPB	15	32.6
Not reported	7	15.2
Environment measures		
GIS	8	17.4
NEWS	14	30.4
Other	30	65.2
Physical activity measures		
3DPAR	3	6.5
Accelerometers	9	19.6

BRFSSS	2	4.3
GLTEQ	6	13.0
IPAQ	10	21.7
Other	17	37.0
Risk of bias assessment		
High quality	1	2.2
Moderate quality	30	65.2
Low quality	15	32.6

*Note.* 3DPAR, 3-day Physical activity Recall; BRFSSS, Behavioral Risk Factor Surveillance System Survey; GIS Geographic Information Systems; GLTEQ Godin Leisure-Time Exercise Questionnaire; IPAQ International Physical Activity Questionnaire; LTPA, leisure-time physical activity; MVPA, moderate-to-vigorous physical activity; NEWS Neighborhood Environmental Walkability Survey; PA, physical activity; SCT, Social Cognitive Theory; TPB, Theory of Planned Behaviour;

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*Table 2. Pathways between environment, social cognition, and total physical activity.*

Correlate	Path B		Path C'		Path AB	
	Association	# Studies	Association	# Studies	Association	# Studies
<u>Social Cognitive Variables</u>						
Perceived Benefits/Attitude	+ (+,INS)	3 (3,0)				
Perceived Barriers	INS (INS,INS)	1 (1,0)				
<u>Affective Judgements</u>						
Subjective Norm	INS (INS,INS)	1 (0,1)				
Social Support	+ (+,+)	6 (3,3)				
Self-Efficacy	+ (+,+)	14 (8,6)				
Intention	+ (?,+)	5 (2,3)				
<u>Environmental Variables</u>						
Aggregate Variable			0 (0,INS)	3(3,0)	INS (INS,INS)	1 (1,0)
Accessibility/Convenience			0 (0,0)	9 (5,4)	+ (+,0)	5 (3,2)
Safety			0 (0,0)	10 (5,5)	0 (? ,0)	6 (2,4)
Quality			0 (0,INS)	5 (4,1)	? (? ,INS)	2 (2,0)
Aesthetics			0 (0,INS)	4 (3,1)	INS (INS,INS)	1 (1,0)

Note: INS = insufficient information to evaluate. + = positive association (>60% of studies supportive). 0 = no association (<34% of studies supportive). ? = mixed evidence (between 59% and 34% of studies supportive). First coefficient is the total summary of all studies. Parentheses include adult studies (18+ years) followed by youth studies (<18 years).

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Table 3. Pathways between environment, social cognition, and moderate to vigorous intensity physical activity.

Correlate	Path B		Path C'		Path AB	
	Association	# Studies	Association	# Studies	Association	# Studies
<u>Social Cognitive Variables</u>						
Perceived Benefits/Attitude	0 (0,INS)	3 (3,0)				
Perceived Barriers	? (?, INS)	2 (2,0)				
Affective Judgements	0 (0,?)	4 (2,2)				
Subjective Norm	INS (INS,INS)	1 (1,0)				
Social Support	0 (0,INS)	5 (5,0)				
Self-Efficacy	+ (+,?)	13 (9,4)				
Intention	+ (INS,+)	2 (0,2)				
Self-Regulation	INS (INS,INS)	1 (1,0)				
<u>Nonconscious Variables</u>						
Habit	INS (INS,INS)	1 (0,1)				
<u>Environmental Variables</u>						
Aggregate Variable			0 (0,INS)	4 (3,1)	0 (0,INS)	3 (2,1)
Accessibility/Convenience			0 (0,0)	11 (7,4)	? (0,?)	10 (6,4)
Safety			0 (0,INS)	4 (3,1)	0 (0,INS)	5 (4,1)
Quality			0 (0,INS)	5 (4,1)	0 (0,INS)	5 (4,1)
Aesthetics			0 (0,INS)	2 (2,0)	0 (0,INS)	3 (3,0)

Note: INS = insufficient information to evaluate. + = positive association (>59% of studies supportive). 0 = no association < 34% of studies supportive). ? = mixed evidence (between 59% and 34% of studies supportive). First coefficient is the total summary of all studies. Parentheses include adult studies (18+ years) followed by youth studies (<18 years).

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*Table 4. Mediation Pathways between environment, social cognition, and leisure-time physical activity.*

Correlate	Path B		Path C'		Path AB	
	Association	# Studies	Association	# Studies	Association	# Studies
<u>Social Cognitive Variables</u>						
Perceived Benefits/Attitude	+ (+,INS)	6 (5,1)				
Perceived Barriers	0 (0,INS)	5 (5,0)				
Affective Judgements	? (?,INS)	4 (4,0)				
Subjective Norm	0 (0,INS)	3 (2,1)				
Social Support	? (?,INS)	7 (7,0)				
Self-Efficacy	? (?,INS)	13 (12,1)				
Intention	+ (+,INS)	7 (6,1)				
Self-Regulation	INS (INS,INS)	1 (1,0)				
<u>Environmental Variables</u>						
Aggregate Variable			+ (+,INS)	3 (3,0)	0 (0,INS)	3 (3,0)
Accessibility/Convenience			0 (0,INS)	10 (9,1)	0 (0,INS)	7 (6,1)
Safety			0 (0,INS)	6 (5,1)	0 (0,INS)	4 (3,1)
Quality			0 (0,INS)	7 (7,0)	0 (0,INS)	6 (6,0)
Aesthetics			0 (0,INS)	7 (6,1)	? (?,INS)	5 (4,1)

Note: INS = insufficient information to evaluate. + = positive association (>59% of studies supportive). 0 = no association (< 34% of studies supportive). ? = mixed evidence (between 59% and 34% of studies supportive). First coefficient is the total summary of all studies. Parentheses include adult studies (18+ years) followed by youth studies (<18 years).

## Environment, Individual, and Physical Activity 39

Table 5. Pathways between environment, social cognition, and active transport physical activity.

Correlate	Path B		Path C'		Path AB	
	Association	# Studies	Association	# Studies	Association	# Studies
<u>Social Cognitive Variables</u>						
Perceived Benefits/Attitude	? (? ,INS)	4 (4,0)				
Perceived Barriers	INS (INS,INS)	1 (1,0)				
Affective Judgements	0 (0,INS)	3 (3,0)				
Subjective Norm	0 (0,INS)	3 (3,0)				
Social Support	0 (0,INS)	4 (4,0)				
Self-Efficacy	? (0,INS)	7 (6,1)				
Intention	? (? ,INS)	5 (5,0)				
<u>Nonconscious Variables</u>						
Habit	+ (+,INS)	2 (2,0)				
<u>Environmental Variables</u>						
Aggregate Variable			0 (0,INS)	2 (2,0)	INS (INS,INS)	1 (1,0)
Accessibility/Convenience			0 (0,INS)	7 (6,1)	+ (+,INS)	5 (4,1)
Safety			0 (0,INS)	6 (5,1)	? (INS,INS)	2 (1,1)
Quality			0 (0,INS)	3 (3,0)		
Aesthetics			0 (0,INS)	3 (3,0)		

Note: INS = insufficient information to evaluate. + = positive association (>60% of studies supportive). 0 = no association (<34% of studies supportive). ? = mixed evidence (between 59% and 34% of studies supportive). First coefficient is the total summary of all studies. Parentheses include adult studies (18+ years) followed by youth studies (<18 years).